cirad
LA RECHERCHE AGRONOMIQUE
POUR LE DÉVELOPPEMENT

The challenge of Guayule

An alternative source of naturel rubber
A model of bio-refinery

S.Palu/D.Pioch/A.Amor/E.Tardan
T.Chapuset/D.Snoeck/ F.Bonfils

IRRDB IRC 2013

24th - 26th June 2013 MILLENNIUM HOTEL MAYFAIR LONDON

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

CONTENTS

1. NEED FOR ALTERNATIVES SOURCES OF NR SUPPLY
2. GUAYULE HISTORY & DEVELOPMENT
3. GUAYULE CULTIVATION SPECIFICITY
4. RUBBER EXTRACTION & PROPERTIES
5. GUAYULE A MODEL OF BIOREFINERY CONCEPT
6. ECONOMICS OF GUAYULE versus HEVEA
7. CONCLUSION & PERSPECTIVES

- In Jl. Rubb. Res. Inst. Sri Lanka **(1977)** 54, 306—315 NATURAL RUBBER — PLANS FOR THE FUTURE, **Dr. B. C. SEKHAR** wrote:

"***Equally important are the considerations now being given to*** *alternatives of NR… consuming countries have come to firmly accept the imperative need of a sole cis-polyisoprenic rubber. They are circumspect on the capacity of NR producing countries to meet projected requirements. The USA and Mexico are reviewing..* ***technical viability of deriving cis-polyisoprene from other rubberbearing plants, such as Guayule…***

. the world requires a substantially larger supply of cis-polyisoprene. Unless this is forthcoming from the most advanced and techno-economically attractive industry, i.e. Hevea, ***the world must look for alternatives. In other words, the natural rubber industry is moving into an exciting and challenging era…."***

- In the grapes of wrath (1939) chapter 9, **John Steinbeck** wrote

"*…remember in the war we planted mustard ? remember a fella wanted us to put in that rubber bush they call guayule ?get rich he said….."*

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

WHY ALTERNATIVES SOURCES OF NR ?

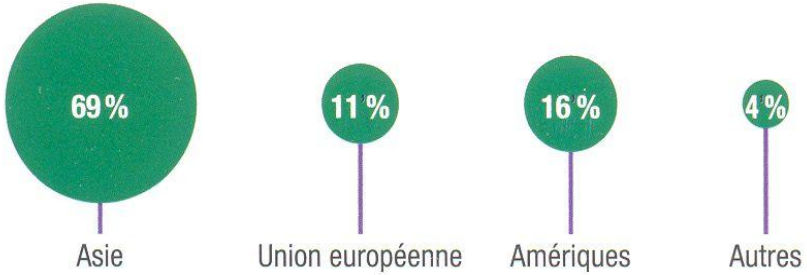
- ***HEVEA*, only commercial source of NR (93% world prod. in Asia)**

- **Growing demand from emerging countries (China, India,..).**

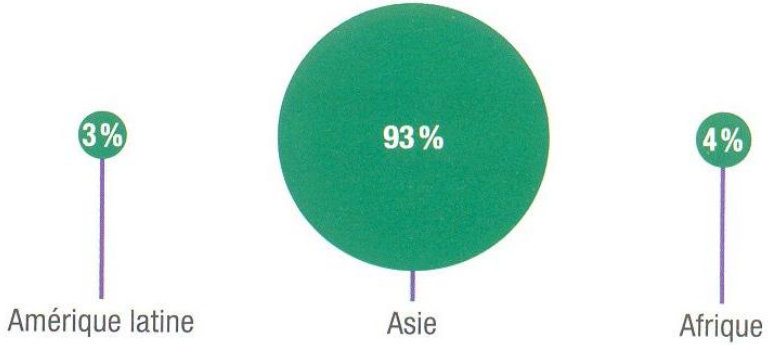
  5.0 M. Tons in 1990 → *17.0 M.T. in 2025*

- **Price NR & SR linked with volatile price of oil (80-150 $/ barrel)**

- **Replacement of rubber plantations by palm oil plantations**



NR Consomption (*source SNCP & IRSG)*



NR Production (*source SNCP & IRSG)*

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

- **NR prices have rocketed upward (4.800€/T. Feb. 2011)**
- **Threat M*icrocyclus ulei* (SALB), South America but risk to spray in Asia/Africa exists. When ? How ? Climatic changes ?**
- **Proteins Hevea cause IgE-latex allergy. Guayule Hypoallergenic.**
- **Rubber tapping manual, laborious, Guayule can be mechanized**

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

HOW TO GUARANTY NR SUPPLY

- **New plantations & replanting**
  8.3 M. ha in production, 11.4 M. ha with young planting.

- **Improve SALB Hevea clonal resistance (IRRDB)**

- **Develop new alternatives sources**
  - ✓ **GUAYULE**
  - ✓ **Khazakstan or Russian DANDELION**

- **Implement European or International projects**
  - ✓ **EU-PEARLS (2008-2012),**
  - ✓ **EAGLES (2011),**
  - ✓ **G-VALUE (2013)…….**

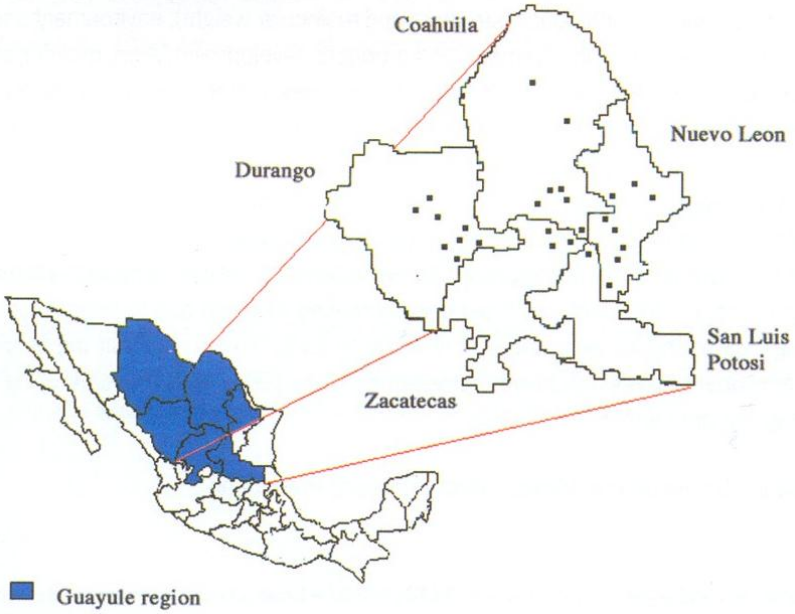
cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

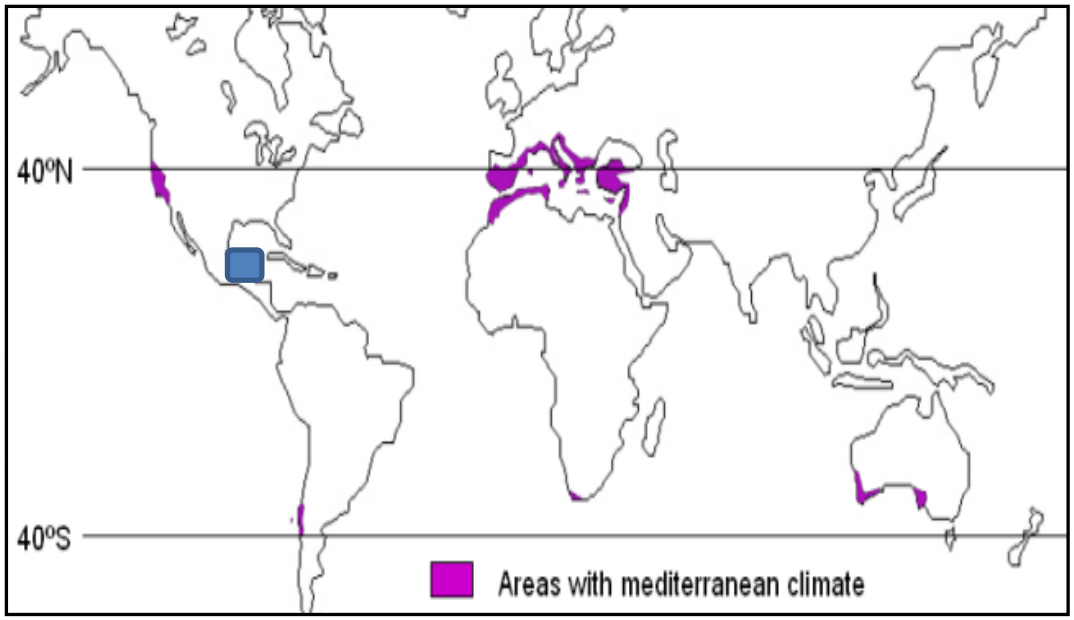
WHAT IS GUAYULE ?

✓A bush, native from Mexico/Chihuahua desert

Asteraceae /Compositae **(*Parthenium argentatum Gray*)**

in the wild, age up to 40 years, commercial up to 10 -12 years

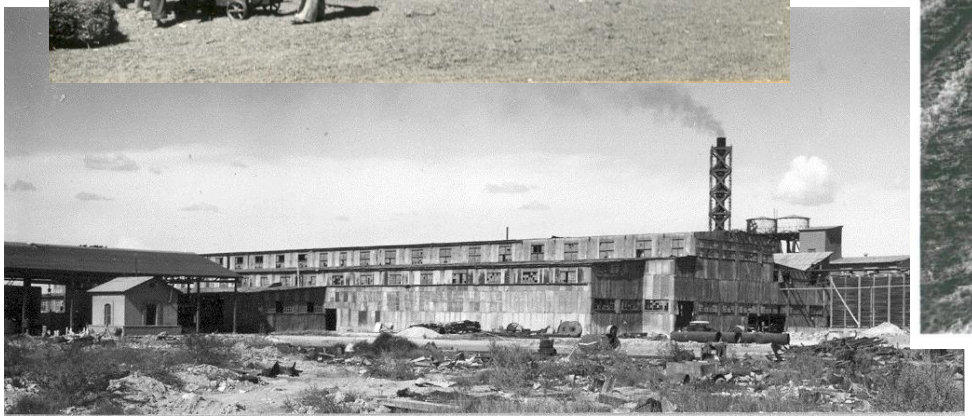




MAIN STEPS OF DEVELOPPMENT

- ✓ 1906-1912: 55.000 T. of GR, < 1000 T. than hevea at same period

- ✓ WWII: Emergency Rubber Project, 8,000 ha, end of the war stopped with new access to hevea plantations in Asia and synthetic rubber development



cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

- ✓ 1970s: Oil embargo. R&D in California, Arizona, Australia, Africa. Firestone project in Texas (Fort Stockton).

- ✓ 1980s: Pilot plant in Saltillo, Mexico. Native Latex commercialization Act (1978) , Firestone plant, Sacaton - Arizona. CIRAD in Morocco & West Africa, Australia, etc...

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

- ✓ 2000s: YULEX, Guayule hypoallergenic latex (K. Cornish)

- ✓ 2008: EU-PEARLS project, G. Fields in France (Montpellier), Spain (Cartagena/Murcia). End 2012 with prototypes + fields in EU

- ✓ 2012: Bridgestone Project on sustainable source of NR,
  Yulex new factory in Chandler, AZ.
  Cooper Tire with Yulex

- ✓ 2013: Bridgestone interest for high value uses of Co-Product.
  New EU projects.
  Yulex with VERSALIS and PIRELLI in Italy.
  PANARIDUS-USA releases GR samples project in India.

IRRDB IRC 2013

24th - 26th June 2013 MILLENNIUM HOTEL MAYFAIR LONDON

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

AGRONOMY OF GUAYULE

✓Commercial conditions: soils well-drained, 12 years, -9°Cmin, 380-640$_{mm}$. Needs of irrigation, nursery plants, density planting 30.000 to 55.000 plants/ha.

➡ **More biomass ≈ more rubber**

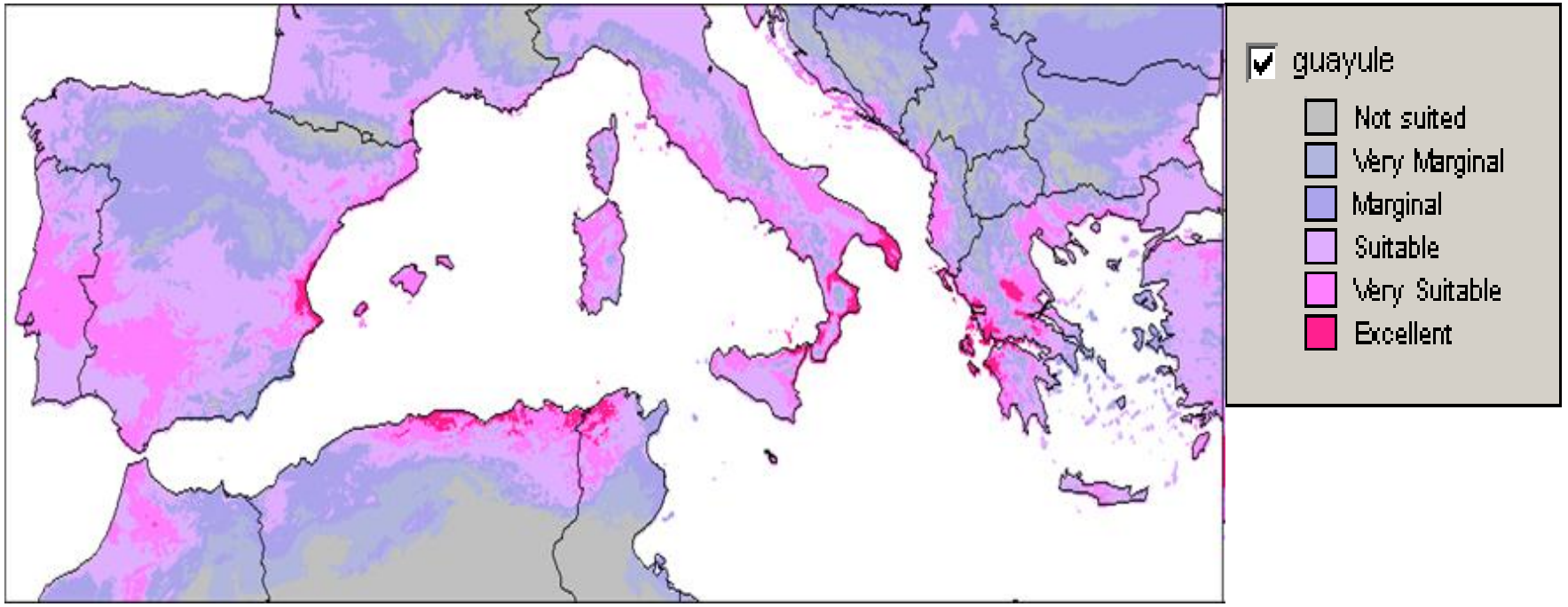
✓Guayule: apomitic, Tetraploids most common form and bigger plants more productive. Best USDA lines : **AZ2, AZ1, AZ3, CAL 6, 11591, N565, 593** (EPR)

➡ **Rubber content 6–12%** **(** dry weight biomass)

81% of rubber in branches, 1% in leaves, 18% in roots

➡ **Yield 0.5-1.0 kg/ha/an** **(harvested every 1-2 years).**

By combining the maps (temperature and rainfaill),
GIS generates a potential land suitability map for guayule, showing six potential yield categories, where optimal conditions exist.



cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

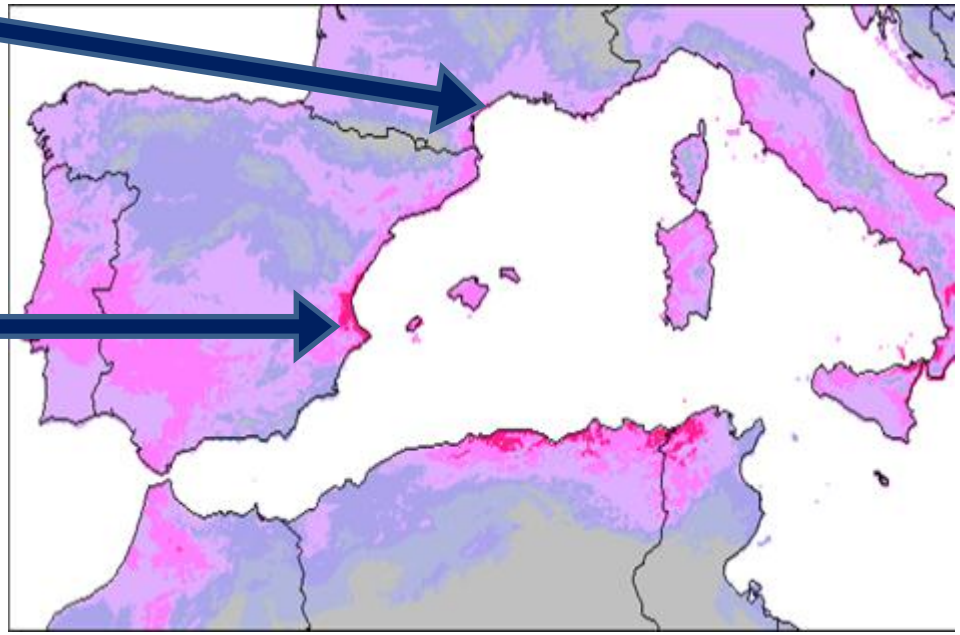
Two sites were selected for EU-PEARLS field trials:

- France, Montpellier
  Agropolis research station

cirad
AGRICULTURAL RESEARCH FOR DEVELOPMENT

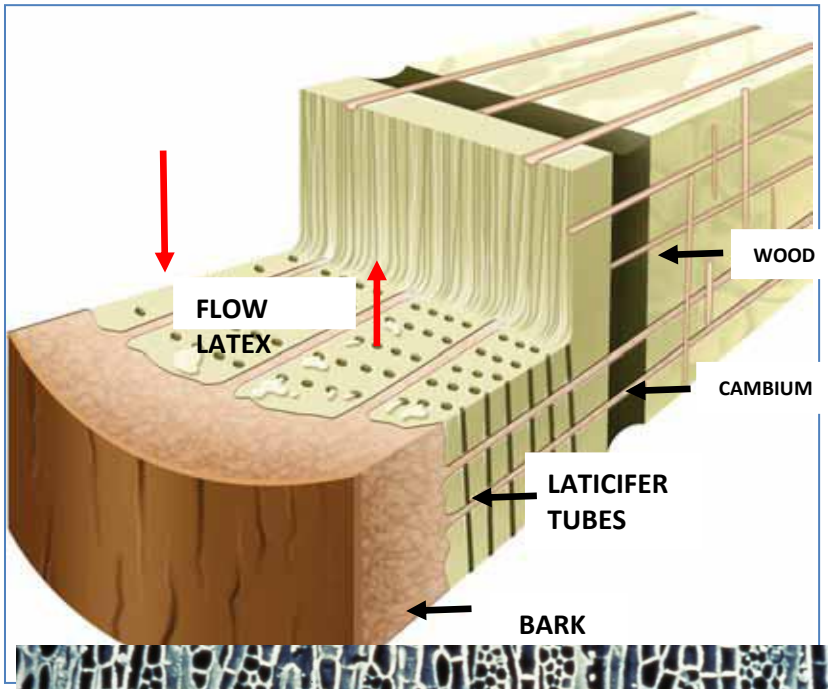
- Spain, Cartagena
  El Molinar farm

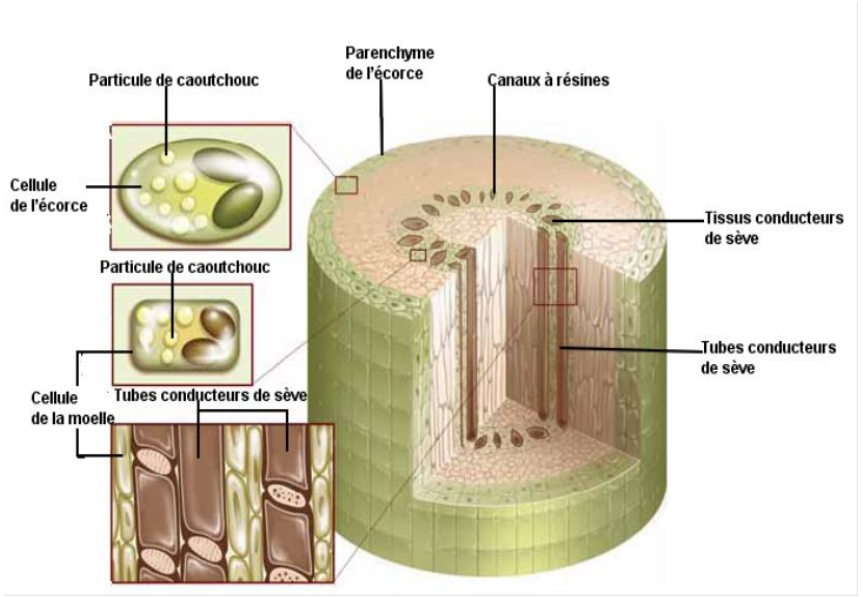
WAGENINGEN UR
For quality of life

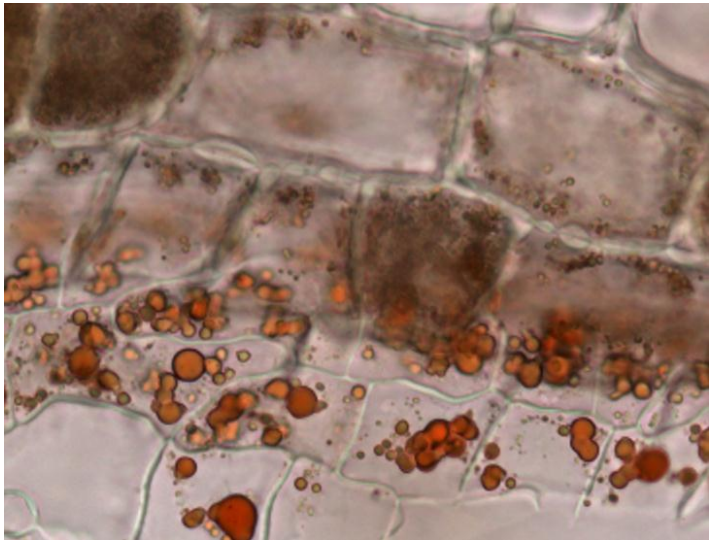


cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

HISTOLOGY HEVEA vs GUAYULE







cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

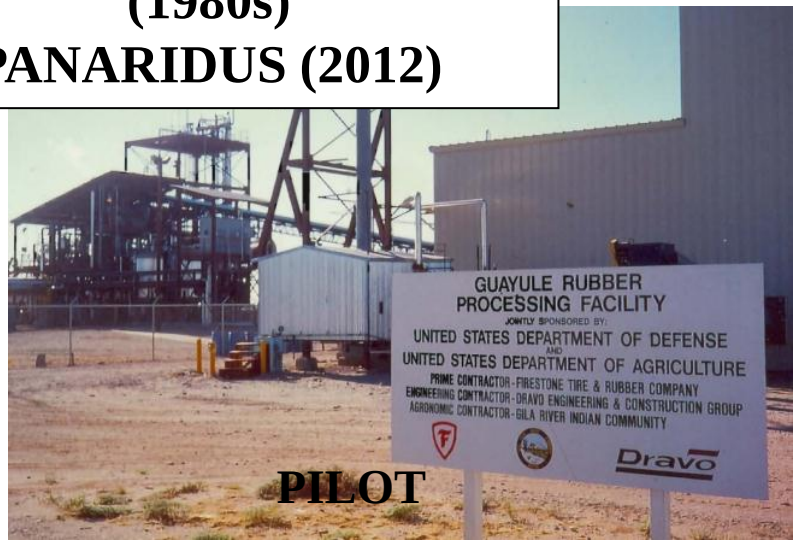
GUAYULE EXTRACTION

HARVEST

LATEX	SOLVENT DRY RUBBER & RESINS	SC FLUID RESINS & Low Mw
YULEX USDA CIRAD	SALTILO / CIQA TEXAS A&M FIRESTONE/SACATON (1980s) PANARIDUS (2012)	USDA,YULEX Laboratory level High Mw ?

RESEARCH LEVEL

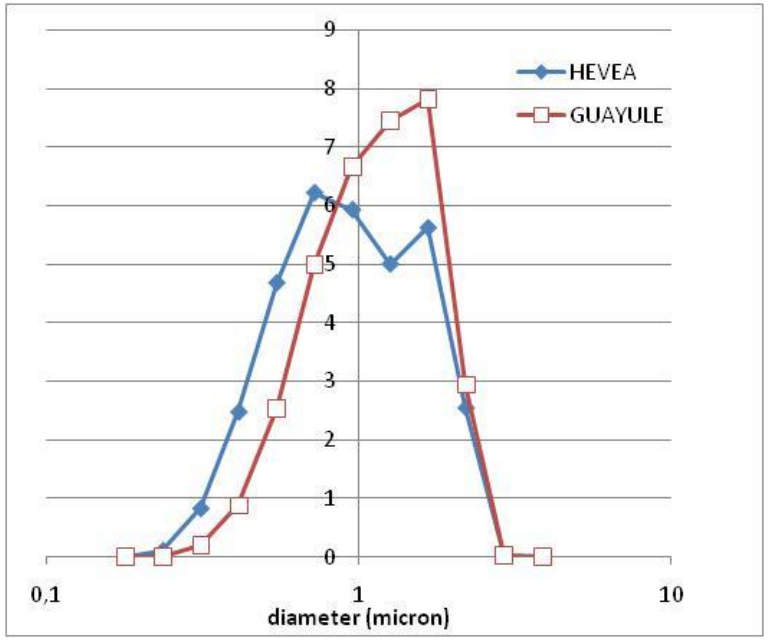
COMMERCIAL (500 T./Y)



PILOT

CTTM
CENTRE DE TRANSFERT
DE TECHNOLOGIE DU MANS

cirad
LA RECHERCHE AGRONOMIQUE
POUR LE DÉVELOPPEMENT



	HEVEA LATEX	COMMERCIAL GUAYULE LATEX*
Solid content (%)	**61.4**	**55.6**
Viscosity (Cp)	**48**	**53**
pH	**9.6**	**10.9**
Average size (µm)	**1.0**	**1.2**

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

GLOVES PROPERTIES

	HEVEA latex	COMMERCIAL GUAYULE latex	EU-PEARLS GUAYULE light phase latex	
Vulcanising dispersion ratio	27	54	54	
Stress at break (Mpa)	17	7.0	13.3	
Strain at break (%)	810	860	808	

GUAYULE and HEVEA gloves mechanical properties are similar after slight formulation and process adaptations

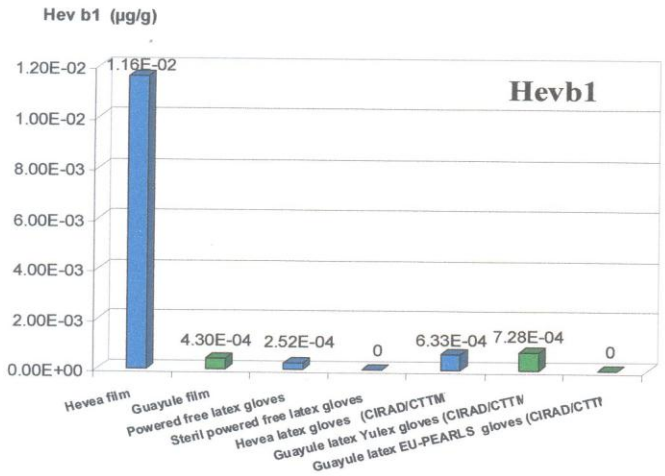
CTTM
CENTRE DE TRANSFERT DE TECHNOLOGIE DU MANS

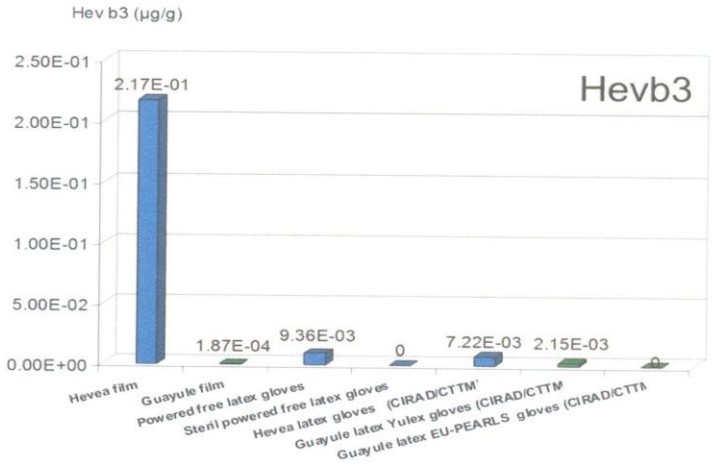
PIERCAN

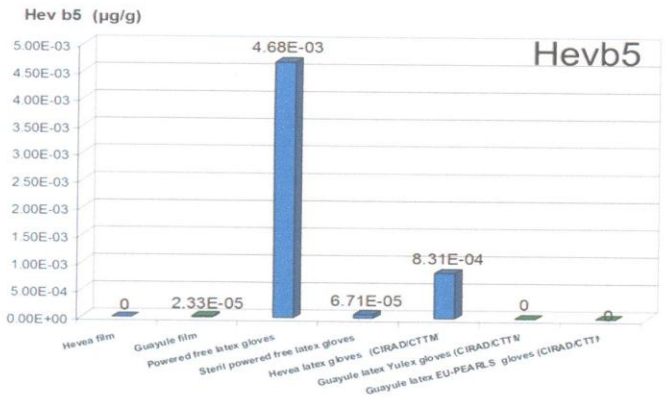
cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

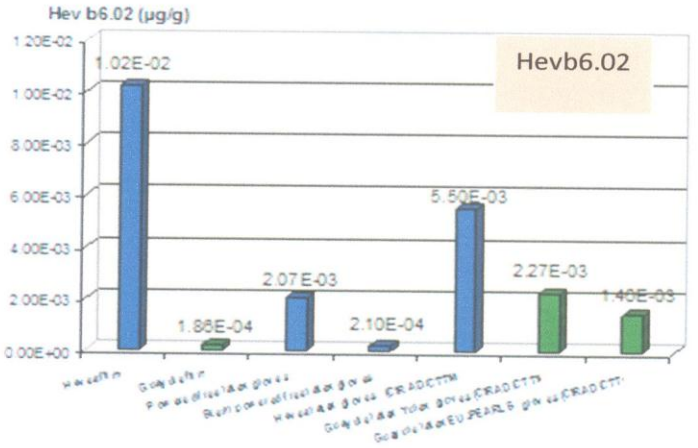
GUAYULE LATEX NO-ALLERGY

Allergy Type I (anaphylactic choc) Allergy Type IV (irritation, cross allergy)







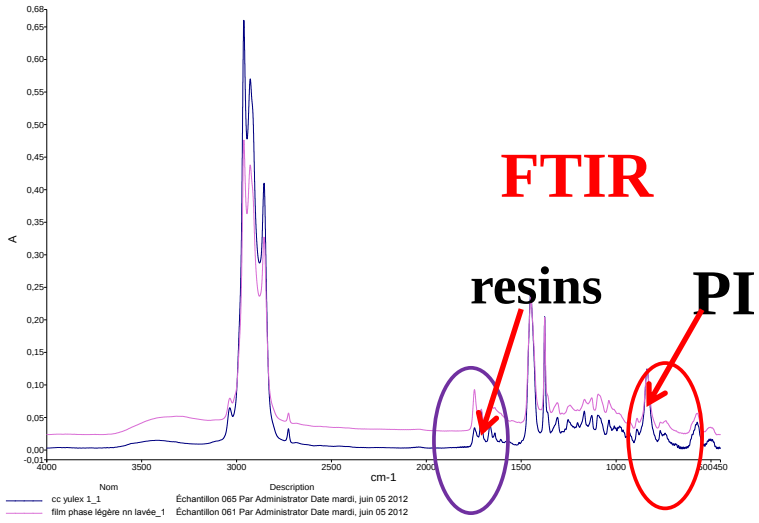


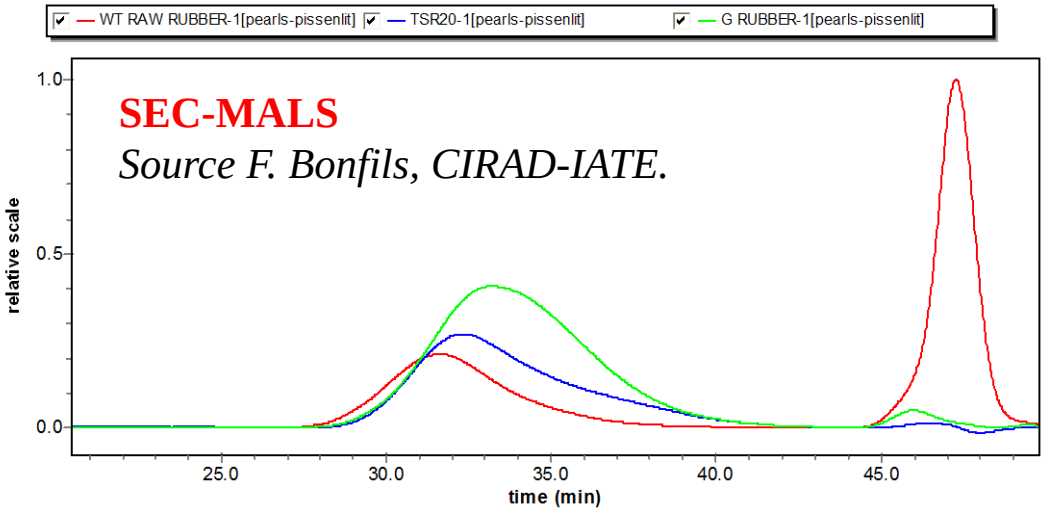
- **ASTM (D6499-00) = ELISA test**
- **FITKit® (test immuno-enzymatic 4 major allergens)**

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

MICROSTRUCTURE CHARACTERISATION

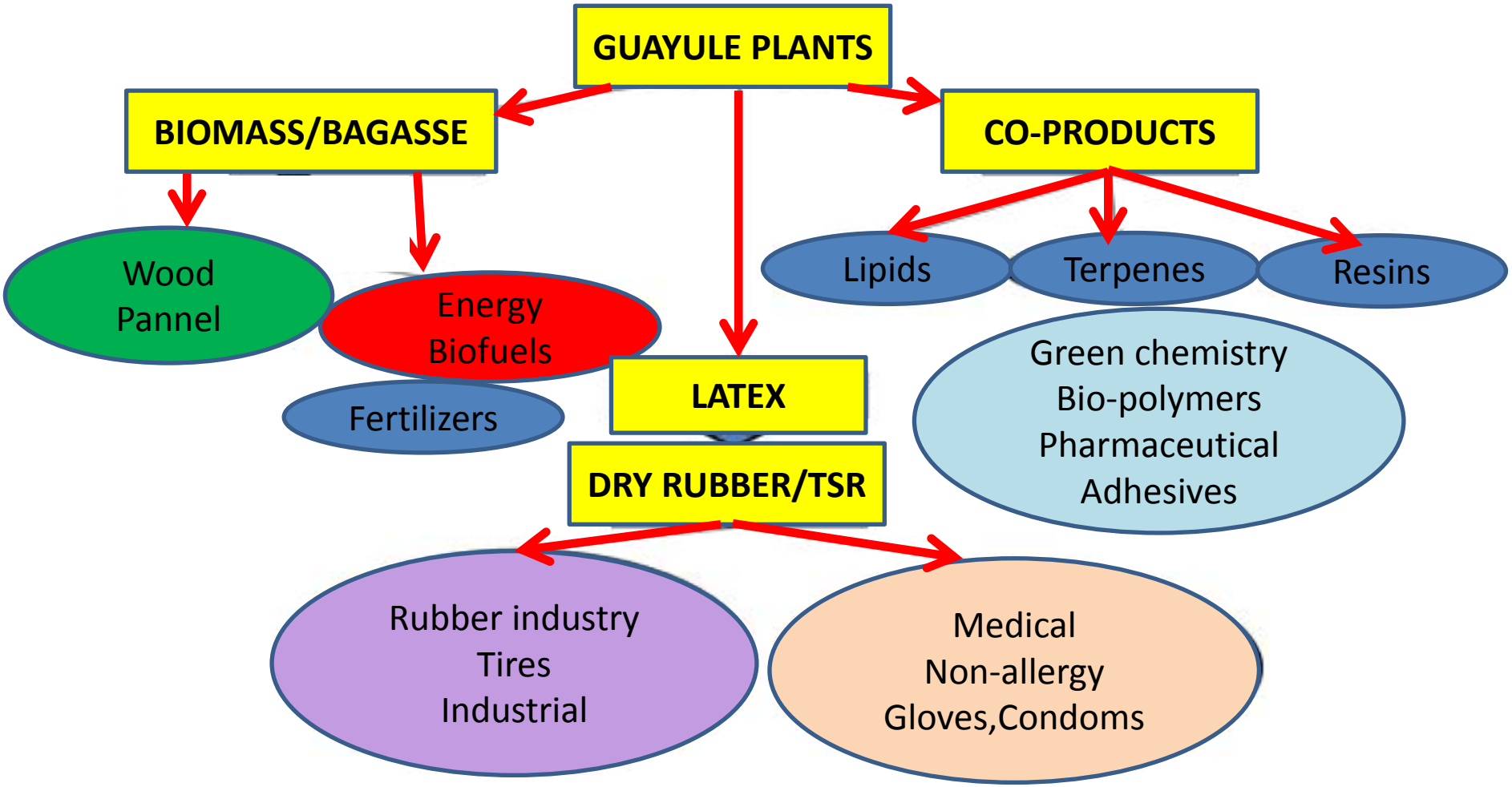
- ✓ **NMR $_{C13}$, FTIR : GR, TKSR and HR , all PI cis 1,4**
- ✓ **SEC-MALS analysis shows molar mass (Mw, Mn) varies with age of plants, storage conditions, type of extraction process, method of measurement, aging. Ratio of gyration (R_g=f(M_w), more branching for GR than HR and TKSR raw rubber**





GR TSR SPECIFICATIONS

PROPERTIES	GR 1	GR 2	HR
Initial Plasticity P0 , ISO 2007	**13**	**31 - 33**	>30
Plasticity retention indice PRI (ISO 2930)	**15.4**	**6.5- 15.2**	**>40**
Mooney Viscosity ML (1+4) 100° C ISO 289-1	25	52 -53	60-80
Dirt content % ISO 249	-	0.016 0.038	<0.20
Acetone extract ISO 1407	12.4	12 -14	<0.5
Ash content % ISO 247	-	0,19- 1.25	<1.00
Total nitrogen ISO 13878	-	0. 21	<0.60



GUAYULE BIO-REFINERY

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

GUAYULE BIO-PRODUCTS

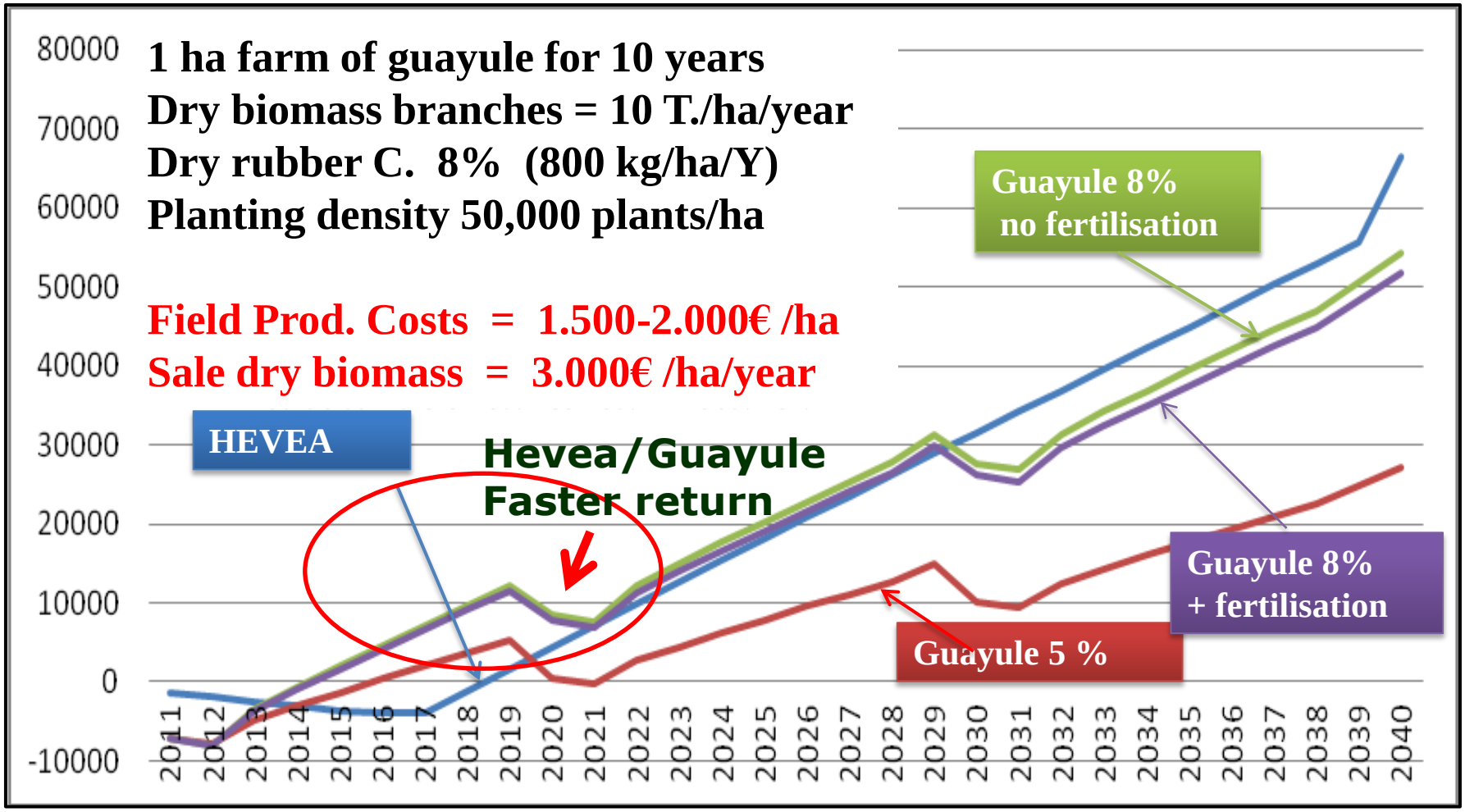
Fraction	Class	Chemicals	Tested applications
Volatile	Terpenes 3-5%	α, β Pinene Camphene, α and β Phellandrene Sabinene, β Myrcene	**Essential oil, Tall oil**
Non-volatile	85-97%		
Water soluble	Short acid, ester Polyphenols	Bornyl acetate, Cinnamic acid Tannins, flavonoides Polysaccharides	**Cockroach attractant**
Water insoluble	Hydrocarbons	α & β Ocimene Limonene	**Termite control** **Nematod control** **Weed control** **Antimicribiol** **Fungistatic** **Adhesives (UF substitutes)** **Strippable coatings** …… New to be discovered
	Fatty acid TG 20-25%	Linoleic (65%), Linolenic, Palmitic , Oleic	
	Wax (leaves)	Carnauba	
	Sesquiterpenes	Guayulines A,B, Partheniol	
	Triterpenes	Argentatine A,B,C,D,E,F,G,H	
	Alkaloid	Guayulamine A,B	

Source Nakayama 2005, Costa et al 1992, Schloman 1983

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

Accumulated balances of hevea and guayule cultivation

Source : Nisrin SFEI IAMM/CIRAD 2011-2012 with « Olympe » software (for publication)



cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

THRESHOLD SELLING PRICE OF GUAYULE RUBBER

Option 1: only Latex (centrifugation)

- With current technology, it is possible to extract 60% of the total rubber as latex.
  - The valorisation of sole guayule latex would be possible only through a niche market with very high added value.

Option 2: only crude rubber + resin (solvent extraction)

- With current technology, it is possible to extract 90 % of rubber + 95 % of the resin.
  - ✓ (*Prices recorded in 2011*).

Option 3: Latex as step 1, followed by **crude rubber + resin** as step 2.

- It is possible to extract 25 % of latex + 65 % of crude rubber + 95 % of resin.

Threshold selling price (€ /kg) to reach profitability

Option	Latex	Crude rubber	Resin
1. Latex only	8.0-9.0		
2. Solvent only		4,0	3,0
3. Latex, then solvent	5.0	3.0	3.0

CONCLUSION

- **Guayule (GR) not a threat to Hevea**

  If Hevea NR capacity not available, alternative raw materials will develop.

- **Commercial production for GR (5000 T. in 2025 ?)**
  - **Price of NR (> 3.0 $US /kg),**
  - **High rubber Yield /ha (≈1 ton/ha target),**
  - **Lower costs of production, efficiency of processing**
  - **New cultivars, genetic improvement,**
  - **Valorisation of bioproducts and bio-refining**

➢ Commercial production for GR depends on:

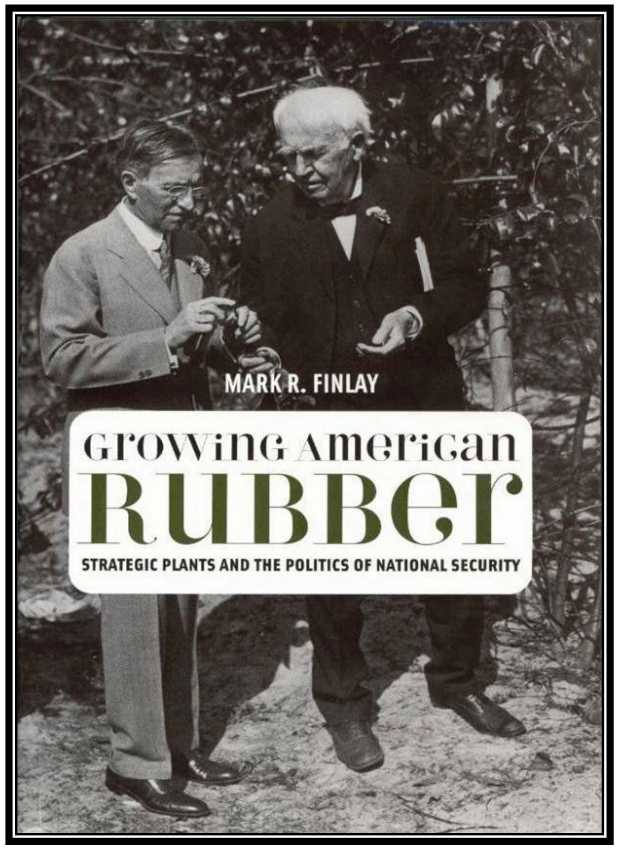
- **Rubber prod. & demand (China, India).**
- **More commercial plants of GR needed with higher capacity, new areas for planting**
- **Tyres and industrial rubber companies, national and international organizations to be involved on alternatives sources of NR.**
- **New cultivars with higher yield (> 1T./Ha/Y)**
- **More economics & feasibility studies**

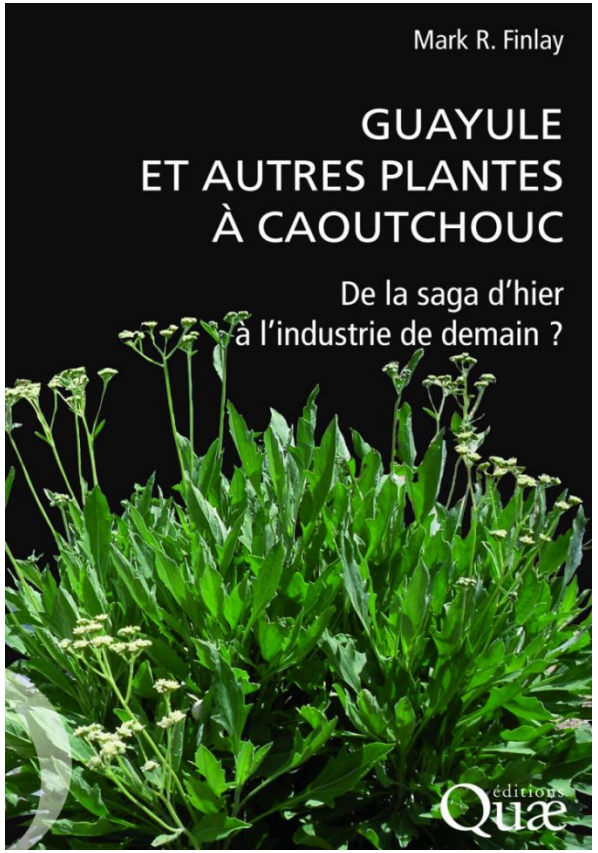
➢ **CIRAD (UR BiowooEB) opened to development on guayule with IRRDB research institutes.**

IRRDB IRC 2013

24th - 26th June 2013 MILLENNIUM HOTEL MAYFAIR LONDON

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT





Growing American Rubber: Strategic Plants and the Politics of National Security
(Mark R. FINLAY, Rutgers University Press, 2009)

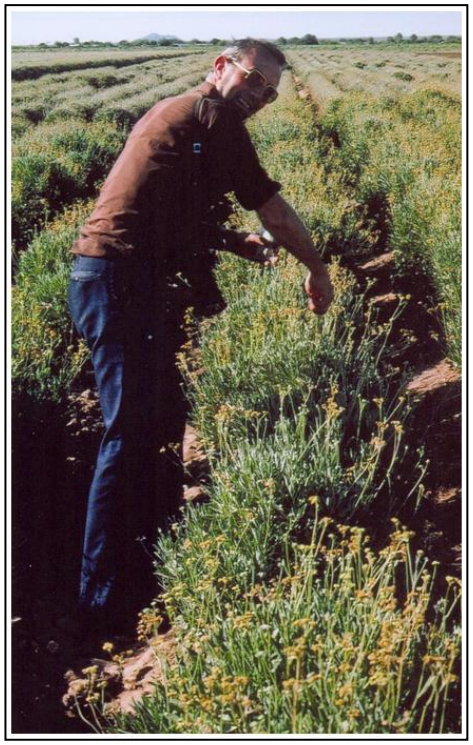
French translation by D.Michelin & CIRAD, **Editions *QUAE*, *March 2013***

IRRDB IRC 2013

24th - 26th June 2013 MILLENNIUM HOTEL MAYFAIR LONDON

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

PAPER PRESENTED IN MEMORY OF



J.B SERIER

IRCA/CIRAD Researcher

&

Dr AFS BUDIMAN

During his PhD at the Institute of Polymer Sciences, Dr AFS Budiman worked on the study of fundamental parameters of guayule deresination 1981-1984

IRRDB IRC 2013

24th - 26th June 2013 MILLENNIUM HOTEL MAYFAIR LONDON

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

"Catch the Alternative Natural Rubber ball"

THANK YOU